ponds. The raphidophytes *Heterosigma akashiwo, Fibrocapsa japonica*, and *Chattonella subsalsa*, also found by SCECAP in South Carolina's coastal waters, have been implicated in numerous fish kills globally (Honjo, 1993).

While none of these species were present in high abundance and no toxins were detected in the samples collected for the SCECAP study, they are present and potentially capable of responding rapidly to future anthropogenic nutrient enrichment. It is imperative that the development of our coastline be tempered by thorough urban planning and effective watershed management in order to prevent harmful algal blooms and ensure the health of our estuaries.

Benthic Communities

Benthic macrofauna serve as ecologically important components of the food web by consuming smaller organisms living in or on the sediments, detritus, or planktonic food sources and in turn serving as prey for finfish, shrimp, and crabs. Benthic macrofauna are also relatively sedentary, and many species are sensitive to varying environmental conditions. As a result, benthic organisms are important biological indicators of water and sediment quality and are useful in monitoring programs to assess overall coastal and estuarine health (Hyland *et al*., 1999; Van Dolah *et al*., 1999).

Mean density of benthic organisms across all stations sampled during the 2003-2004 study period varied from 63 to 37,113 individuals/m^2 (mean= 3,628 individuals/m^2). The mean density of organisms collected in open water habitats (4,182 individuals/m^2) was greater than the density in tidal creek habitats (3,076 individuals/m^2), although the difference was not statistically significant ($p = 0.952$, Figure 3.4.4). The density of benthic organisms in open water habitats has been consistently higher than in tidal creek habitats in all three surveys conducted by SCECAP to date (Van Dolah *et al*., 2002a; 2004a). The mean density of organisms collected during the 2003-2004 study period was 25% lower than the mean density collected in the 1999-2000 study period (average = 4,722 individuals/m^2) and 30% lower than those collected in 2001-2002 (average = 5,208 individuals/m^2). The first two study periods (1999-2002) occurred during a drought period in South Carolina (South Carolina State Climatology Office), while the current study period began after the drought was lifted in April, 2003. The differences in benthic faunal density may reflect changes in salinity between the previous study periods when drought conditions persisted (Van Dolah *et al*., 2002a; 2004a) and the current study period when more normal rainfall patterns returned (see section 3.2 and Box 3.4.2).

The overall number of species (species richness: S) varied from two to 64 taxa per grab (average = 17), and species diversity (H') varied from 0.40 to 4.49 (average = 2.62). The mean number of species

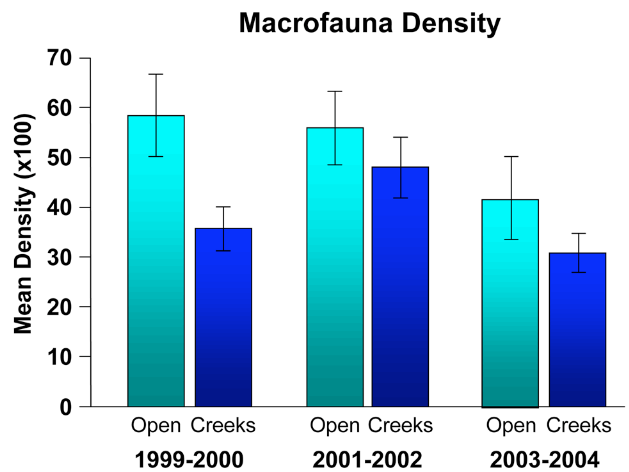


Figure 3.4.4. Mean density (number per m^2) of benthic fauna collected in open water and tidal creek habitats during the three study periods.

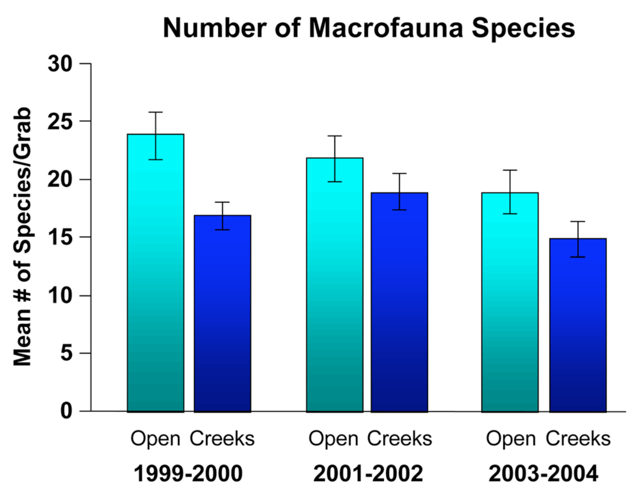
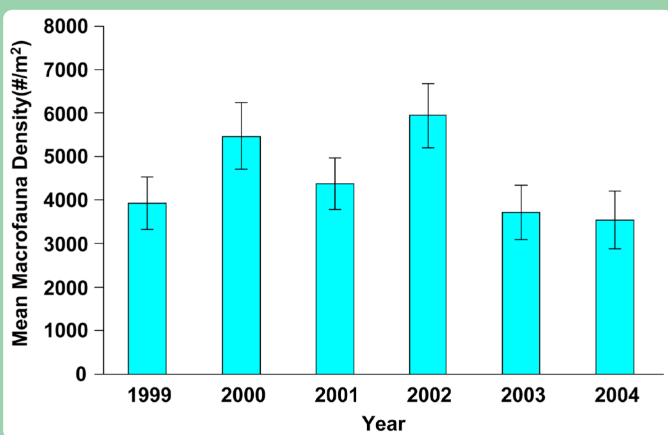


Figure 3.4.5. Mean number of species of benthic fauna collected in open water and tidal creek habitats during the three study periods.

Box 3.4.2 Rainfall, Salinity and Benthic Invertebrates

How does salinity affect estuarine benthic communities?

Salinity in an estuary varies with daily tides, season, volume of fresh water inflow, and proximity to the open ocean. Estuarine salinities are usually highest at the mouth of a river where ocean water enters, and lowest upstream where freshwater inflow is greatest. However, drought conditions can significantly alter the water quality of an estuary, particularly by allowing high salinity water to penetrate further upstream. Salinity is the major natural environmental factor controlling the distribution of benthic organisms in estuaries (Attrill & Power, 2000; Magnien *et al*., 1987). While benthic estuarine fauna are adapted to handling a fairly broad range of salinities, unusually high or low salinities and large changes in salinity can negatively affect their survival, growth and reproduction. During the current SCECAP study period, average salinity decreased and salinity ranges increased in both tidal creek and open water habitats as compared to previous study periods. Concurrent with this change was a 30% decrease in the mean number of organisms per m^2 collected by SCECAP sampling in South Carolina's sediments. Additionally, seven stations sampled in the current study period had salinity ranges greater than 20 ppt throughout a 25-hour monitoring period. Six of those stations also had low densities of benthic organisms (<1000/m^2), suggesting evidence of biological stress. This trend may reflect salinity effects directly, but it also may reflect other factors associated with increased terrestrial runoff, such as increased contaminant loads.



Abundance of benthic organisms (mean number per m^2) collected each year since the start of SCECAP monitoring in 1999.

and overall species diversity per grab were higher in open water habitats (S = 18.8, H' = 2.75) than in tidal creek habitats (S = 15.2, H' = 2.49) during the current study period (Figure 3.4.5). Although not significant, the trend of higher values at open water stations was also observed in the two previous study periods. No significant differences were observed in the average number of species or diversity estimates per grab among the three survey periods conducted to date, when all stations were considered collectively or when both habitat types were compared separately.

In order to compare the general taxonomic composition of organisms collected during each study period, all benthic species were classified into one of four groups: polychaetes, amphipods, mollusks, or other taxa (primarily oligochaetes, nemerteans, isopods, and decapods). The mean abundances of amphipods and mollusks were significantly greater in open water than in tidal creek habitats (p = 0.013; p=0.032, respectively). Polychaetes and other taxa were found in greater abundances in tidal creek habitats than in open water habitats, but these differences were not significant (p > 0.05). The percent abundance of polychaetes observed in both habitat types during 2003-2004 was very similar to that observed in the 1999-2000 survey, but about 10% lower than observed during the 2001-2002 survey period (Figure 3.4.6). Slightly higher percentages of amphipods and lower percentages of other taxa were found during the current sampling period at open water habitats when compared to the two previous study periods, while the opposite trend was observed at tidal creek habitats (Van Dolah *et al*., 2002a; 2004a). Minimal

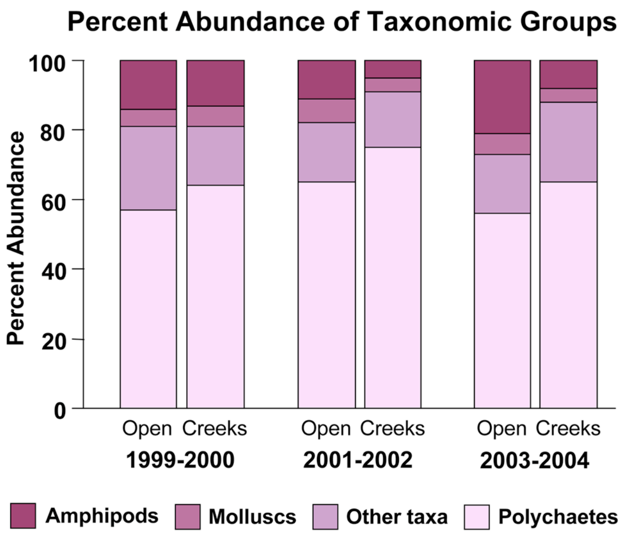


Figure 3.4.6. Percent abundance of organisms representing general taxonomic groups collected in benthic grabs at open water and tidal creek sites during the three study periods.

changes in mollusk abundances were observed across all study periods.

The number of species in each taxonomic category varied by habitat type. Open water stations collectively included 144 polychaete species, 48 amphipod species, 56 mollusk species, and 77 other taxa. Tidal creek stations collectively included 119 polychaete species, 38 amphipod species, 47 mollusk species, and 64 other taxa. There were significantly more amphipod species found at open water stations than at tidal creek stations sampled during the current study ($p = 0.009$). The number of species representing the other taxonomic groups (polychaetes, mollusks, and other taxa) were not significantly different between the habitat types. There were few significant differences between study years with respect to the number of species representing various taxonomic categories in either open water or tidal creek stations. One exception was a significantly greater number of polychaete species in tidal creek habitats during the 2001-2002 study period than during the 2003-2004 study period ($p = 0.037$).

The five dominant taxa collected during the 2003-2004 study period comprised 29% of the overall abundance across all stations (Table 3.4.2). These taxa included the polychaetes *Streblospio benedicti*, *Scoletoma tenuis*, *Mediomastus* sp. and *Tharyx acutus*, and the amphipod *Ampelisca abdita*. Of the five most abundant taxa, only *A. abdita* occurred at less than 50 percent of the stations sampled (Table 3.4.2). Nemertean worms (the 24th most abundant taxon) occurred at the largest percentage of stations (65%). Two of the five dominant taxa collected in 2003-2004, *S. benedicti* and *S. tenuis*, were also among the five dominant taxa collected in the 1999-2000 and 2001-2002 study seasons (Van Dolah *et al*., 2002a; 2004a).

In open water habitats, the five most abundant taxa also comprised 29% of the total abundance and included the polychaetes *S. tenuis*, *S. benedicti*, *Sabellaria vulgaris* and *Exogene* sp. and the amphipod *A. abdita*. The polychaete *Caulleriella* sp. was among the top five organisms collected in open water habitats in the previous two study periods, but was substantially less abundant during 2003-2004 (Table 3.4.2). The five most abundant taxa in tidal creek habitats together comprised over 38% of the total abundance of benthic tidal creek fauna and included *S. benedicti*, *S. tenuis*, *T. acutus*, *Mediomastus* sp. and the oligochaete *Tubificoides wasselli*. *Streblospio benedicti*, *T. wasselli*, and *S. tenuis* have been among the top five taxa collected in tidal creek habitats during all three study periods.

Streblospio benedicti, the numerically dominant species overall and in tidal creek habitats, was found in significantly greater abundances in tidal creek habitats than in open water habitats ($p = 0.004$). The same trend was observed in the 1999-2000 study period, but *S. benedicti* was found in significantly greater abundances in open water habitats during the 2001-2002 study period (Van Dolah *et al*., 2002a; 2004a). *Streblospio benedicti* is generally sensitive to changes in salinity, and its abundance tends to decrease at lower salinities (Reish, 1979). Over the three study periods, the average salinity in tidal creek habitats has consistently decreased (see section 3.2), and *S. benedicti* abundances have as well. The second most abundant organism in tidal creek habitats was the oligochaete *T. wasselli*, but it was not particularly abundant in open water habitats. During previous study periods, *T. wasselli* was among the top ten numerically dominant organisms in both open water and tidal creek habitats. However, *T. wasselli* prefers a mesopolyhaline (5-30 ppt) environment. The amount of coastal estuarine habitat in this salinity

Table 3.4.2. Densities and percent occurrences of the 50 numerically dominant benthic organisms collected in 2003 and 2004, which represent 82% of the overall abundance. A = amphipod, M = mollusk, P = polychaete, O = other taxa.

				Open Water		Tidal Creek	
Species Name		Mean Total Abundance at All Stations (#/grab)	% of Stations Where Present	Mean Abundance by Station (#/grab)	% of Stations Where Present	Mean Abundance by Station (#/grab)	% of Stations Where Present
Streblospio benedicti	P	1640	63	7	52	20	75
Scoletoma tenuis	P	947	52	9	43	7	60
Ampelisca abdita	A	925	38	13	33	2	42
Mediomastus sp.	P	686	57	7	57	4	57
Tharyx acutus	P	673	50	6	48	5	52
Sabellaria vulgaris	P	666	22	10	28	1	15
Tubificoides wasselli	O	657	34	2	32	9	37
Exogone sp.	P	553	29	7	35	2	23
Tubificoides brownae	O	412	46	4	43	3	48
Actiniaria	O	412	21	3	23	4	18
Scoloplos rubra	P	305	44	2	35	4	53
Paraprionospio pinnata	P	296	36	3	38	2	33
Polydora cornuta	P	273	28	1	23	4	33
Parapionosyllis sp.	P	262	12	3	17	1	7
Nereis succinea	P	233	43	1	37	2	48
Tubificidae sp. b	O	222	30	2	32	1	28
Caulleriella sp.	P	212	13	0	15	3	12
Spiochaetopterus costarum oculatus	P	200	32	2	32	2	32
Ampelisca verrilli	A	197	16	2	20	1	12
Melita nitida	A	196	23	1	20	2	25
Heteromastus filiformis	P	195	43	0	27	3	58
Scolecolepides viridis	P	191	10	2	8	2	12
Nemertea	O	183	65	1	68	2	62
Aphelochaeta sp.	P	180	26	1	22	2	30
Tubificidae	O	177	25	1	18	2	32
Polydora socialis	P	168	27	1	32	2	22
Carinomella lactea	O	160	33	2	35	1	32
Batea catharinensis	A	151	22	2	28	0	15
Cyathura burbancki	O	142	21	2	27	1	15
Paracaprella tenuis	A	135	17	2	22	1	12
Mediomastus californiensis	P	134	14	2	15	0	13
Protohaustorius deichmannae	A	132	8	2	13	0	2
Tellina agilis	M	131	27	2	32	1	22
Aricidea wassi	P	126	13	2	25	0	2
Polycirrus sp.	P	125	7	2	7	1	7
Tubificoides heterochaetus	O	119	12	1	10	1	13
Aricidea bryani	P	119	24	1	23	1	25
Mediomastus ambiseta	P	117	23	1	28	1	18
Acanthohaustorius millsi	A	114	6	2	8	0	3
Monticellina sp.	P	112	19	1	22	1	17
Leptonacea sp.	M	111	16	2	23	0	8
Phoronida	O	109	16	1	15	1	17
Cirrophorus sp.	P	103	25	1	30	1	20
Unciola serrata	A	101	5	2	10	0	0
Sphenia antillensis	M	97	23	1	25	0	22
Cirratulidae	P	96	31	1	30	1	32
Streptosyllis sp.	P	86	21	1	25	0	17
Leitoscoloplos fragilis	P	81	34	1	38	1	30
Glycera americana	P	78	44	1	45	1	43
Pelecypoda	M	73	33	1	40	0	25

range was approximately 8% lower (see section 3.2) than we observed in the the 2001-2002 study period, a loss that may account for the lower *T. wasselli* abundance. In 2003-2004, *Scoletoma tenuis* was the second most numerically abundant organism over all habitat types and was among the top five dominant organisms found in open water habitats. There were no significant differences in abundances of *S. tenuis* in tidal creek versus open water habitats in the current study ($p = 0.282$).

SCECAP uses a single multi-metric benthic index of biological integrity (B-IBI) to distinguish between degraded and undegraded environments in southeastern estuaries (Van Dolah *et al*., 1999). A number of metrics (i.e., abundance, number of species, and abundance of sensitive taxa) have been integrated into the B-IBI in order to summarize benthic community condition in coastal habitats. About 70% of South Carolina's open water and 71% of tidal creek habitat sampled in 2003-2004 had a healthy benthic community (Table 3.4.3). There has been an apparent decrease in the amount of habitat supporting healthy benthic communities (ie., coding as good benthic condition) since the initial 1999-2000 survey (open water = 16% decline, tidal creek = 13% decline; Van Dolah *et al*., 2002a, 2004a). The amount of South Carolina's coastal habitat that supported benthic communities having some evidence of possible degradation (ie., coding as fair benthic condition) was approximately 22% in open water habitat and 21% in tidal creek habitats. Both habitat types have shown an increase in the percentage of habitat having only fair benthic community condition since the 1999-2000 study (Table 3.4.3). Approximately 8% of the coastal open water and tidal creek habitat had a poor benthic community condition, which represents an approximate increase by 6% in open water habitat and 4% in tidal creek habitat since the inception of the program.

Table 3.4.3. Percent of habitat with B-IBI values indicating good (undegraded), fair (marginally degraded), or poor (degraded) benthic conditions.

	Percent of Habitat B-IBI					
	Open Water			Tidal Creek		
Study Period	Good	Fair	Poor	Good	Fair	Poor
1999-2000	86	12	2	84	12	4
2001-2002	83	14	3	69	27	4
2003-2004	70	22	8	71	21	8

When evaluating B-IBI scores on a yearly basis, there is clearly a trend of decreasing percentage of coastal habitat which supports healthy benthic communities in South Carolina (Figure 3.4.7), with associated increases in the percentages of coastal habitats which have fair and poor benthic community condition. While we didn't observe similar trends in water quality or sediment quality conditions over the course of the study, there has been an increase in ERM-Q (see section 3.3) in coastal areas. The contribution of rising contaminant levels to the decreasing B-IBI is unclear, particularly considering the concomitant changes in salinity during this time.

Finfish and Crustacean Communities

South Carolina estuaries support a diverse array of fish and crustaceans that are dependent on estuarine habitats for food and shelter (Joseph, 1973; Mann, 1982; Nelson *et al*., 1991). Estuaries represent a naturally stressful environment due to broad fluctuations in physical conditions (temperature, salinity, etc) and biological pressures such as predation and competition with other species. In addition, anthropogenic stressors such as recreational and commercial fishing, boating activity, upland development, storm water inputs, and habitat modifications are all placing additional pressures on South Carolina's essential estuarine habitats. Changes to these coastal ecosystems will ultimately lead to changes in the fish and crustacean communities that are dependent upon them (Monaco *et al*., 1992).

Community Composition:

A total of 14,912 organisms representing 72 species were collected by trawl during the 2003-2004 survey (data online). Mean faunal density across all stations varied from four to 4,790 individuals per hectare (individuals/ha) with an overall average of 714 individuals/ha. The mean density in tidal creeks (1040 individuals/ha) was more than twice the mean density in open water habitats (388 individuals/ha), a statistically significant difference ($p < 0.001$). The trend of higher mean faunal densities in tidal creek

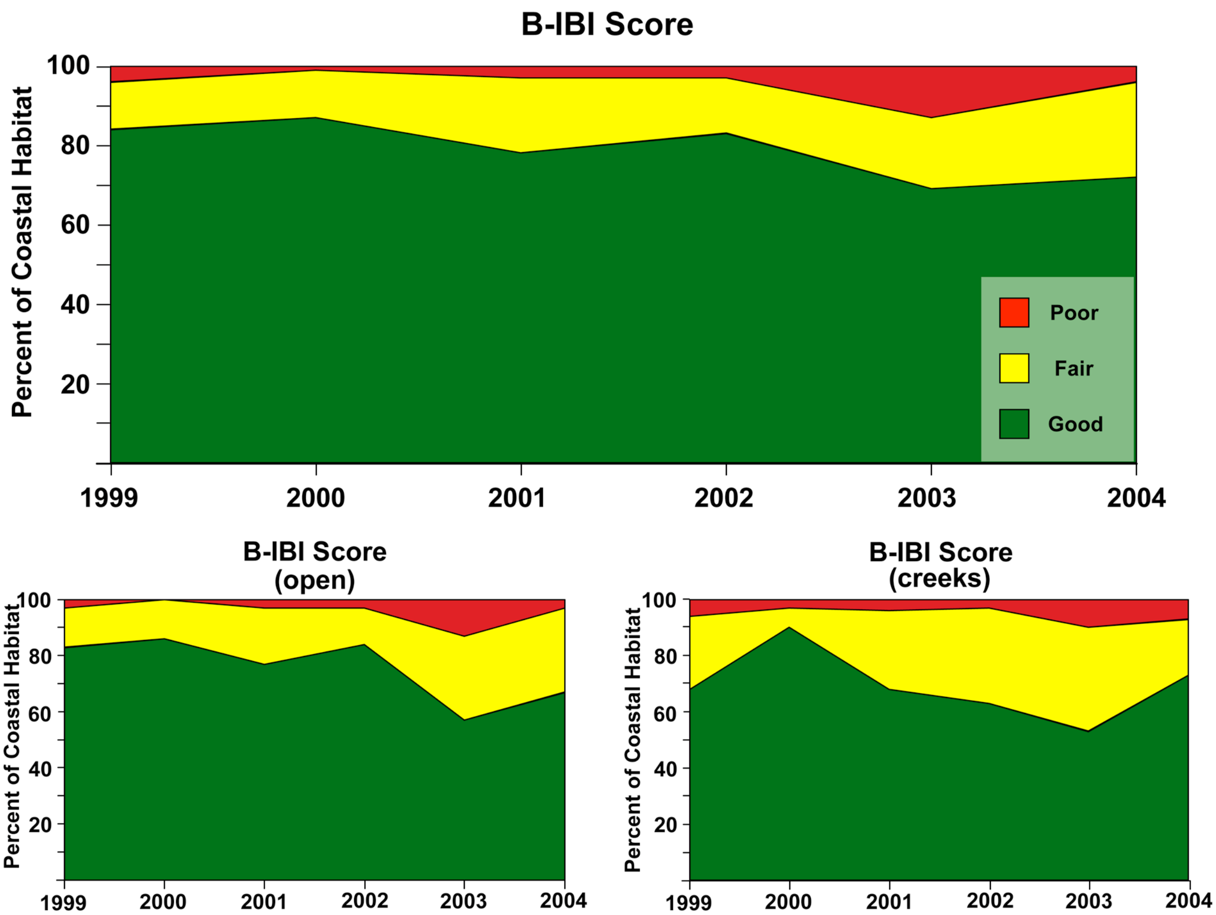


Figure 3.4.7. Proportion of the South Carolina's estuarine habitat that ranks as good (green), fair (yellow) or poor (red) using the benthic index of biological integrity (B-IBI) values compared on an annual basis when tidal creek and open water habitats are combined and for tidal creek and open water habitats considered separately.

stations compared to open water stations has been observed in all three of the survey periods evaluated by SCECAP to date (Van Dolah *et al*., 2002a, 2004a).

The average number of species collected across all stations was 5.9 and varied from 1 to 15 per trawl. Evenness values (J') averaged 0.66 and varied from 0.00 to 1.00, and overall community diversity (H') averaged 1.62 and varied from 0.00 to 2.96. The mean number of species per trawl was slightly higher in tidal creek habitat than in open water habitats (open water = 5.5, tidal creek = 6.4; p = 0.084), but J' (open water = 0.68, tidal creek = 0.65; p = 0.516) and H' (open water = 1.58, tidal creek = 1.67; p = 0.502) were similar. Similar trends were observed for both species numbers and diversity in previous survey periods (Van Dolah *et al*., 2002a, 2004a). While the number of species appears to be greater in tidal creek habitats, it is actually likely to be much greater in open water habitats (Box 3.4.3). Trawls in tidal creeks initially catch more species because fish and crustaceans occur at much higher densities there. However, open water habitats ultimately support more species, likely due to their proximity to the higher salinity open ocean and greater diversity of habitat types. This highlights the different roles filled by these habitats. Productive tidal creek habitats provide forage and nursery habitat for high-density populations of fish and crustaceans, while open water habitats serve as reservoirs of biodiversity.

The 50 most numerically abundant taxa comprised 99.8% of the overall abundance across all stations and included 23 recreationally and/or commercially important species (Table 3.4.4). The five most numerically abundant species were white and brown shrimp (*Litopenaeus setiferus* and *Farfantepenaeus aztecus*), pinfish (*Lagodon*